# RODENT POPULATIONS, BIOMASS, AND COMMUNITY RELATIONSHIPS IN *ARTEMISIA TRIDENTATA*, RUSH VALLEY, UTAH

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ABSTRACT.— Three desert *Artemisia tridentata* communities in Rush Valley, Utah, were trapped for small rodents during the summer of 1970, and population densities were estimated for each population category using Lincoln's index. Animals were weighed and rodent biomass calculated by species throughout the summer. Population, biomass, and other data were then analyzed to gain an understanding of the community relationships of the three study areas to each other as well as to the *A. tridentata* community types of the Great Basin.

*Peromyscus maniculatus*, *Eutamias minimus*, and *Reithrodontomys megalotis* were common to area 1, whereas *P. maniculatus*, *E. minimus*, and *Perognathus parvus* were common to areas 2 and 3. The peak estimated standing crops were 182.8 (74.0), 143.1 (57.9), and 129.7 g/acre (52.5 g/ha) for areas 2, 1, and 3 respectively. The population and biomass of area 2 peaked in midsummer, area 1 early summer, and area 3 late summer.

## INTRODUCTION

Big sagebrush (*Artemisia tridentata* Nutt.) covers an estimated total area of 226,364 square miles (586,283 km²) in the Great Basin and associated areas of the western United States (Beetle, 1960) and is the most abundant plant species over much of this area. According to Hironaka (1963), "*A. tridentata* has the widest distribution of all the sagebrushes and occurs across the entire moisture gradient of the sagebrush zone." Passey and Hugie (1962) found *A. tridentata* occupying a greater number of soil types than any other sagebrush species.

*A. tridentata* is ecologically significant in that it provides not only food and cover for some species but competes against other desirable food and cover species. For economic reasons, however, many people consider sagebrush to be a highly undesirable plant. As a result, much research done in the sagebrush community has been directly concerned with controlling its spread and decreasing its abundance. Treatment resulting from such research has sometimes been temporarily effective. Some treated areas after 14 years may have more sagebrush on them than adjacent untreated areas (Johnson, 1969). The mean useful life cycle of spraying projects throughout Wyoming has been estimated to be about 15 years (Kearl, 1965).

The economic importance and ecological impact of such control measures make research leading to an understanding of the *A. tridentata* community imperative. The objective of this study is to establish baseline data by estimating the comparative small rodent density and biomass of *A. tridentata* communities in low-intermediate- and high-altitude desert areas of the Great Basin and using this estimation to compare the three communities.

Rush Valley, Utah, was chosen for the area of research because (1) it is a designated grazing research area of the Intermountain Forest and Range Experimental Station, which funded the project; (2) a large part of the valley is covered by *A. tridentata;* (3) the data gathered will augment that of current and past research in the valley; and (4) the data collected will aid future studies and management of the valley.

No literature relating rodent density with biomass or energy flow has been published concerning sagebrush communities. There are works, however, that have been reported for other terrestrial communities. Densities of rodents have been studied in Rush Valley, Utah, primarily in pinyon-juniper and reseeded areas (Baker, 1969). Woodbury (1955) reported on the small mammal distribution in Cedar Valley which borders Rush Valley on the east. Vest (1962) reported on the small mammal distribution in Dugway Valley which borders Rush Valley on the west. Rodents of sagebrush communities in both valleys were discussed.

Although literature concerning biomass in *A. tridentata* communities is sparse,

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much descriptive material is available on the plant and its community type. A morphological life history of *A. tridentata* was written by Diettert (1938), and Beetle (1960) published a taxonomic and distributional study of all the north American sagebrush taxa. Other references concerning *A. tridentata* communities in Utah may be found in Christensen (1967).

## Materials and Methods

### Study Areas

Three 14.5 acre (5.87 ha) study areas located in the southern part of Rush Valley, Tooele County, Utah, were selected and are described in Table 1. Area 1, elevation 5,100 feet (1,554 m), is located in the southwest quarter of Section 10, Township 7 south, Range 5 west, Tooele County, Utah. It contains irregularly scattered *A. tridentata* interspersed with *Chrysothamnus puberulus*, the grass *Distichlis stricta*, and bare ground. *Distichlis stricta*, an indicator of alkaline soil conditions, is abundant in a number of small areas with poor drainage as are numerous *A. tridentata* plants 1-3 inches (2.5-7.6 cm) tall. This short sagebrush is possibly stunted by an accumulation of soil salts. The area has a wash 1-2 feet (0.3-0.6 m) deep and five feet (1.5 m) wide that runs across the west side.

Area 2, elevation 5,700 feet (1,737 m) is located in the northwest quarter of Section 35, Township 8 south, Range 6 west, Tooele County, Utah, and is characterized by scattered *A. tridentata* with some *Sarcobatus vermiculatus* and much bare ground. The west boundary of this area is a dirt road, beyond which there is an extensive stand of *S. vermiculatus* mixed with the grass *Agropyron cirstatum.*

Area 3, elevation 6,500 feet, (1,981 m) is located in the west half of Section 4, Township 9, Range 5 south, Tooele County, Utah, and is covered with irregularly scattered *A. tridentata* with a dense understory of a perennial lupine and various grasses, principally *Agropyron dasystachyum* and *Sitanion hystrix.* There is little bare ground except on the east and west borders which were exposed when adjacent land was cleared of *A. tridentata* and some *Juniperus osteosperma* in the fall of 1969.

Vegetation sampling on all areas consisted of measuring (1) absolute ground cover, (2) percent species cover composition, (3) frequency and density of perennial species other than grasses, (4) frequency of all grasses, both annuals and perennials, lumped together, and (5) frequency of all annuals, except grasses, lumped together. A modified line-point method of sampling was used to determine cover, and small quadrats were used for frequency and density data collection (Cain and Castro, 1959). These data are available in Nicholes (1972).

### Trapping

Each of the quadrat study areas, 14.5 acres (5.87 ha), was equally divided into 25 squares with a trap station located in the center of each square where three Sherman aluminum live traps were

Table 1. General comparisons of the study areas.

| Characteristics | Area 1 | Area 2 | Area 3 |
|---|---|---|---|
| [1]Soil type | deep silt-clay alkali soils of the arid & semi-arid valley bottoms | deep silt-loam soils of the semiarid valley bottoms | deep, loamy, dry soils of the dry subhumid alluvial fans |
| Slope | 0-2% | 1-5% | 1-25%, most less than 10% |
| Water runoff | slow | slow to medium | slow to medium |
| Erosion | slight to moderate | high | moderate |
| [1]Climate | | | |
| Mean annual temp. | 51 F | 48 F | 45-47 F |
| Mean annual prec. | 8-10 inches | 8-12 inches | 12-15 inches |
| Principal cover | *Artemisia tridentata*<br>*Chrysothamnus puberulus*<br>*Distichlis stricta* | *Artemisia tridentata*<br>*Sarcobatus vermiculatus*<br>various grasses | *Artemisia tridentata*<br>Lupine sp.<br>various grasses |
| Principal rodents | *Peromyscus maniculatus*<br>*Eutamias minimus*<br>*Reithrodontomys megalotis* | *Peromyscus maniculatus*<br>*Eutamias minimus*<br>*Perognathus parvus* | *Peromyscus maniculatus*<br>*Eutamias minimus*<br>*Perognathus parvus* |
| Elevation | 5,100 ft. (1,554 m) | 5,700 ft. (1,737 m) | 6,500 ft (1,981 m) |

[1](Harvey and Woodward, 1969)

placed. The trapping stations were 160 feet (48.8 m) apart. Rolled oats were used as bait. The traps were set in the afternoon, checked each morning, and closed until the afternoon resetting. Each trapping period covered five consecutive nights, every other week from 2 June to 14 August 1970 (Table 2). The three areas were trapped simultaneously for six trapping periods. To offset bias prior to each trapping period, the sequence in which each of the three areas would be checked and reset was determined randomly. This sequence was maintained throughout a trap period.

At the end of six trapping periods each area was "kill trapped" to compare with live trapping success during the previous periods. A "kill trapping" consisted of one night of live trapping with one live trap set at each of the regular trapping stations, one live trap placed at the corners of each square, and one live trap placed at the middle of each side of the squares, for a total of 121 traps. Before the second trap night each live trap was replaced by two museum special snap traps for a total of 242 traps per quadrat. This trapping pattern continued three to four nights until the number of previously marked animals caught was reduced to none or nearly none. The "kill trapping" did not occur simultaneously for each area because of the large number of traps involved (Table 2).

Animals were toe clipped for identification. Data recorded for each individual animal handled during the study included (1) species, (2) sex, (3) age, (4) weight, (5) trapping station, and (6) notes concerning the animal's general condition,

TABLE 2. Schedule of trapping periods.

| [1]Dates | Areas 1 | 2 | 3 |
|---|---|---|---|
| Live Trapping | | | |
| 1. 2-6 June | X | X | X |
| 2. 15-19 June | X | X | X |
| 3. 29 June-3 July | X | X | X |
| 4. 13-17 July | X | X | X |
| 5. 27-31 July | X | X | X |
| 6. 10-14 Aug. | X | X | X |
| "Kill Trapping" | | | |
| 7. 24-27 Aug. | X | | |
| 8. 31 Aug.-4 Sept. | | | X |
| 9. 6-9 Sept. | | X | |

[1]Dates extend from the first morning traps were checked to the last morning traps were checked during a trap period.

such as pregnancy, parasitism, injuries, and others. Age classes of juvenile, subadult, and adult were determined primarily by pelage color and molt patterns; but the appearance of genitals, behavior of animals, and, in cases where age is extremely difficult to determine, i.e., chipmunks, the weights of the animals were considered. Animals were weighed using a spring-operated scale accurate to the nearest 0.5 g.

### Population and Biomass Estimation

For each species caught and recaptured in sufficient numbers, population estimates were made at the end of each trapping period using Lincoln's, Hayne's, and Jolly's indices (Giles, 1969). Estimates were made for (1) the total species population, (2) the population of each age class within the species, and (3) the population of each sex within the species. Nichols (1972) presents this data. Comparison of the three estimators showed Lincoln's and Hayne's to be similar, but Lincoln's estimates were used in the biomass calculations. Population estimates for "kill trapping" periods were made after the first two nights of trapping, since two nights of "kill trapping" may have caused abnormal immigration into the areas. All other population estimates were calculated using five days of live trapping data.

Species biomass was calculated by multiplying the mean species weight by the estimated population number of that species for each trapping period. Previous experience had shown that animals repeatedly caught during a trapping period tended to lose weight, likely due to trapping stress. To compensate for this, the mean weights were calculated two different ways: (1) using only the weight of an animal taken the first day during a given trapping period and (2) using the weight of an animal taken every day during its captivity for a given trapping period. The greatest of these mean weights for any population category was used in this study. In most instances method one was used.

## RESULTS

Four species of rodents were recaptured in sufficient numbers to be considered in detail, but only three were prevalent in any given area. These species were—

| | Area 1 | Area 2 | Area 3 |
|---|---|---|---|
| *Peromyscus maniculatus* | X | X | X |
| *Perognathus parvus* | | X | X |
| *Reithrodontomys megalotis* | X | | |
| *Eutamias minimus* | X | X | X |

The Lincoln population estimate for each species caught during each trapping period and study area is given in Table 3. The combined total number of rodents estimated, of all species considered, for each area is graphically shown in Figure 1. The following is a general breakdown of each area's trapping according to species. Detailed charts and tables of data are given in Nichols (1972).

### Area 1

*Peromyscus maniculatus.* The greatest number of *P. maniculatus*, 47 (Lincoln's estimate 50), appeared during trap period 3 with a male-female ratio of nearly 2:1. There were 16 juveniles, 30 subadults, and 1 adult. The least number, 24 (Lincoln's estimate 25), composed of 3 juveniles, 17 subadults, and 4 adults with a male-female ratio of 5:3, appeared during period 1. The greatest mean species weight, 19.6 g, occurred during period 1 and the least, 15.5 g, during period 5.

*Reithrodontomys megalotis.* In area 1 *R. megalotis* was captured least often of the main species. The greatest number, 14 (Lincoln's estimate 18), appeared during period 2 with a male-female ratio of 3:4. There were no juveniles, 2 subadults, and 12 adults. During periods 4, 5, and 6 no mice of this species were caught. The greatest mean species weight, 13.9 g, occurred in period 3 and the least, 11.1 g, in period 2.

*Eutamias minimus.* The greatest number of *E. minimus*, 33 (Lincoln's estimate 33), appeared during period 1 with a male-female ratio of approximately 3:2. There were 16 juveniles, 14 subadults, and 3 adults. The least number, 10 (Lincoln's estimate 8), composed of 0 juveniles, 9 subadults, and 1 adult with a male-female ratio of nearly 1:1, appeared during period 6. The greatest mean species weight, 30.5 g, occurred during period 5 and the least, 28.4 g, during period 4.

### Area 2

*Peromyscus maniculatus.* The greatest number of *P. maniculatus*, 49 (Lincoln's estimate 43), appeared during trap period 6 with a male-female ratio of nearly 3:2. There were 5 juveniles, 38 subadults, and 6 adults. The least number, 13 (Lincoln's estimate 12), composed of 6 juveniles, 5 subadults, and 2 adults with a male-female ratio of 5:8, appeared during period 2. The greatest mean species weight, 18.2 g, occurred during period 5 and the least, 15.3 g, during period 1.

*Perognathus parvus.* In area 2 *P. parvus* was captured least of the three main species. Both periods 5 and 6 yielded the greatest number, 10 (Lincoln's estimates 9 and 10), with male-female ratios of 7:3 and 3:1. The respective age distributions were 0 and 2 juveniles, 9 and 7 subadults, 1 and 1 adults. The period of least capture was period 1 when one adult female was captured. The greatest mean species weight, 18.7 g, occurred during period 2 and the least, 14.5 g, during period 3.

*Eutamias minimus.* The greatest number of *E. minimus*, 43 (Lincoln's estimate 46), appeared during period 2 with a male-female ratio of approximately 4:3. There were 20 juveniles, 16 subadults, and 7 adults. The least number of chipmunks, 14 (Lincoln's estimate 13), composed of 1 juvenile, 12 subadults, and 1 adult with a male-female ratio of nearly 4:1, appeared during period 3. The greatest mean species weight, 31.1 g, occurred during period 5 and the least, 27.7 g, during period 1.

### Area 3

*Peromyscys maniculatus.* The greatest number of *P. maniculatus*, 55 (Lincoln's estimate 49), appeared during trap period 3 with a male-female ratio of approximately 3:5. There were 16 juveniles, 31 subadults, and 8 adults. The least number, 29 (Lincoln's estimate 26), composed of 2 juveniles, 18 subadults, and 9 adults with a male-female ratio of 3:4, appeared during period 1. The greatest mean species weight, 19.9 g, occurred during period 1 and the least, 17.5 g, during period 6.

*Perognathus parvus.* The greatest number of *P. parvus*, 47 (Lincoln's estimate 54), appeared during period 6 with a

TABLE 3. Estimated population numbers and biomass for the three study areas.

| | | Lincoln's $\widehat{\underline{N}}$ no./14.5 acres (5.86 ha) | | | Estimated biomass (g/14.5 acres) (5.86 ha) | | |
|---|---|---|---|---|---|---|---|
| Trap Period | Species | Area 1 | Area 2 | Area 3 | Area 1 | Area 2 | Area 3 |
| 1 | P.M. | 25 | 18 | 26 | 490.0 | 275.4 | 517.4 |
| | E.M. | 33 | 34 | | 943.8 | 941.8 | |
| | P.P. | | | 25 | | | 530.0 |
| | R.M. | | | | | | |
| | | 58 | 52 | 51 | 1433.8 | 1217.2 | 1047.4 |
| 2 | P.M. | 44 | 12 | 36 | 752.4 | 199.2 | 698.4 |
| | E.M. | 39 | 46 | | 1123.2 | 1311.0 | |
| | P.P. | | 1 | 40 | | 18.7 | 836.0 |
| | R.M. | 18 | | | 199.8 | | |
| | | 101 | 59 | 76 | 2075.8 | 1528.9 | 1534.4 |
| 3 | P.M. | 50 | 16 | 49 | 875.0 | 283.2 | 886.9 |
| | E.M. | 31 | 13 | | 914.5 | 374.4 | |
| | P.P. | | 2 | 29 | | 29.0 | 559.7 |
| | R.M. | 1 | | | 13.9 | | |
| | | 82 | 31 | 78 | 1803.4 | 686.6 | 1446.6 |
| 4 | P.M. | 48 | 26 | 55 | 811.2 | 434.2 | 1078.0 |
| | E.M. | 23 | 28 | | 653.2 | 848.4 | |
| | P.P. | | 8 | 36 | | 148.0 | 655.2 |
| | R.M. | | | | | | |
| | | 71 | 62 | 91 | 1464.4 | 1430.6 | 1733.2 |
| 5 | P.M. | 41 | 27 | 58 | 635.5 | 491.4 | 1044.0 |
| | E.M. | 5 | 24 | 2 | 152.5 | 746.4 | 68.4 |
| | P.P. | | 9 | 38 | | 162.9 | 767.6 |
| | R.M. | | | | | | |
| | | 46 | 60 | 98 | 788.0 | 1400.7 | 1880.0 |
| 6 | P.M. | 35 | 43 | 47 | 591.5 | 722.4 | 822.5 |
| | E.M. | 8 | 59 | | 242.4 | 1770.0 | |
| | P.P. | | 10 | 54 | | 158.0 | 1015.2 |
| | R.M. | | | | | | |
| | | 43 | 112 | 101 | 833.9 | 2650.4 | 1837.7 |
| 7 | P.M. | 33 | | | 488.4 | | |
| | E.M. | 12 | | | 337.2 | | |
| | | 45 | | | 825.6 | | |
| 8 | P.M. | | | 43 | | | 705.2 |
| | E.M. | | | 3 | | | 91.5 |
| | P.P. | | | 47 | | | 794.3 |
| | | | | 93 | | | 1591.0 |
| 9 | P.M. | | 61 | | | 1067.5 | |
| | P.P. | | 6 | | | 85.2 | |
| | | | 67 | | | 1152.7 | |

Key: P.M.—*Peromyscus maniculatus;* E.M.—*Eutamias minimus.* P.P.—*Perognathus parvus.* R.M.—*Reithrodontomys megalotis.*

male-female ratio of approximately 7:5. There were 4 juveniles, 21 subadults, and 22 adults. The least number, 19 (Lincoln's estimate 25), composed of 0 juveniles, 3 subadults, and 16 adults with a male-female ratio of nearly 2:1 appeared during period 1. The greatest mean species weight, 21.2 g, occurred during period 1 and the least, 18.2 g, during period 4.

*Eutamias minimus.* In area 3 *E. minimus* was captured the least of the three main species. The greatest number, 6 (Lincoln's estimate 0), appeared during period 6 with a male-female ratio of 1:2. There were 0 juveniles, 3 subadults, and 3 adults. No chipmunks were caught during period 3. The weight, 39.0 g, of one adult female, the only animal caught during period 1, represents the greatest mean species weight. The least mean species weight was 29.5 g and occurred during period 3.

Estimated Small Rodent Biomass

The estimated biomass of each species for every period and study area, along with total biomass per area, is given in Table 3. In addition Table 3 lists the Lincoln population estimates used in the biomass computations. Kill-trap data were not included in calculating the greatest, least, and mean area biomass as given in the following description of rodent biomass by areas, but they are included in Table 3. The kill-trap biomass for any of the three areas fell within the limits of the estimates for that particular area from the six previous trapping periods.

*Area 1.* The greatest estimated small rodent biomass, 143.1 g/acre (57.0 g/ha), for area 1 occurred during period 2. The least, 54.3 g/acre (22.0 g/ha), occurred during period 5. The mean biomass of area 1 over the six trapping periods was 96.5 g/acre (39.1 g/ha). The mean was approached during periods 1 and 4. Periods 5 and 6 were well below the mean as was kill-trap period 7.

*Area 2.* The greatest biomass, 182.8 g/acre (74.0 g/ha), for area 2 occurred during period 6. The least, 47.4 g/acre (19.2 g/ha), occurred during period 3. The mean biomass of area 2 over the six trapping periods was 102.5 g/acre (41.5 g/ha). The mean was approached during periods 2, 4, and 5. Area 2 had the greatest and the lowest biomass of all three areas during the study.

*Area 3.* The greatest biomass, 129.7 g/acre (52.5 g/ha), for area 3 occurred during period 5 and the least, 72.2 g/acre (29.2 g/ha), occurred during period 1. The mean biomass of area 3 over the six trapping periods was 109.9 g/acre (44.5 g/ha). The mean was approached during period 2 and kill-trap period 8.

## Discussion

To understand an *A. tridentata* community a knowledge of the associated vertebrates and vegetation must be obtained. An analysis of each *A. tridentata* study area is thus important in a discussion relating the rodent population and biomass of the individual areas to each other to establish the picture for the community type.

*Peromyscus maniculatus* and *E. minimus* were two of the three predominant rodent species in each area. This could be expected for *P. maniculatus* because of its geographic range over most North American biomes (Burt and Grossenheider, 1964; King, 1968), including sagebrush regions of the Great Basin. *Eutamias minimus* also has a broad geographical range, including the Great Basin and much of Canada. Its appearance on all study areas should also be expected since it is characteristic of sagebrush communities (Gordon, 1943; Burt and Grossenheider, 1964). Out of 43 vertebrate species noted during the study, 15 were common to all three areas, an indication that the study areas were similar. Table 1, however, indicates that notable differences existed between them. These differences resulted from the distribution of the 28 vertebrates which were not common to the three areas (Nichols, 1972). Area 1 had 4, area 2 none, and area 3 12 unique species of vertebrates present. The large number of unique species for area 3 can be explained by the presence of a more diverse habitat than in the other areas. This diversity was likely due to more favorable climatic and edaphic factors (Table 1). Area 2 was intermediate in soil, slope, temperature, and precipitation (Table 1). The lack of vertebrate species unique to area 2 also indicates that it was an intermediate area.

Area 1 exhibited the least vertebrate diversity, area 2 was transitional but closer to area 1, and area 3 was the most diverse. Most of the rodent biomass for areas 1 and 2 came from *E. minimus*, while their contribution in area 3 was small (Table 3). This supports the apparent closer relationship of area 2 to area 1. It should also be kept in mind that areas 1 and 3 are the farthest apart geographically and altitudinally, with area 1 (elev. 5,100 ft.; 1,554 m) near the valley floor, area 3 (elev. 6,500 ft.; 1,981 m) at the base of the valley-forming mountains, and area 2 (elev. 5,700 ft.; 1,737 m) on the benchland between them.

The ground cover of each area was dominated by *A. tridentata*, although each area had a different predominant understory species (Nichols, 1972). The diversity pattern reflected was one of low plant species diversity for areas 1 and 2 and high diversity for area 3. Area 1 had 14, 2 had 15, and 3 had 30 plant species present. This was similar to the vertebrate diversity pattern for the respective areas. This similarity in vertebrate and plant diversity patterns was likely due to the edaphic and climatic factors affecting the plants which in turn affected the vertebrates. The lack of complete similarity between vertebrate and plant patterns, however, may have been due to the physiognomic differences of the cover species present in the areas rather than the amount of diversity.

It is suggested that the amount, distribution, and physiognomy of dominant vegetative cover in *A. tridentata* communities may have a greater influence than the diversity of cover species in determining vertebrate presence. Turner (1950) supports this idea, especially for *Peromyscus* distribution, in his study of 10 vegetative types, including 3 having *A. tridentata* as the dominant or codominant plant. Rosenzweig and Winakur (1969) have hypothesized from studies in the lower-Sonoran desert scrub vegetation that "the spatial variations in density of some species [rodent] are responses to spatial characteristics of their environment. Important among these environmental characteristics tend to be measures of the presence and/or absence of vegetation of various physiognomies."

The absolute cover of *A. tridentata* in area 1 was 17.6 percent; 2 was 15.5 percent; and 3 was 23.2 percent. Percent cover composition was 44.2 percent (area 1), 48.0 percent (area 2), and 38.0 percent (area 3). Area 2 had the least absolute cover of *A. tridentata* with the most bushes less than 2 feet (0.6 m) high but had the greatest percent cover composition of *A. tridentata* for the three areas. This cover pattern may have been why area 2 had no unique vertebrates, thus functioning as a limiting factor to diversity. Area 1 had four species but was no more diverse than area 2 in terms of plant species, indicating that in this case cover type had a greater effect than did plant diversity. Area 3, in terms of *A. tridentata* cover, was opposite area 2. Area 3 had the greatest absolute coverage of *A. tridentata* with most bushes greater than 2 feet (0.6 m) high but had the least *A. tridentata* cover composition for the areas. This showed the opposite effect on vertebrate presence than the pattern in area 2. Instead of having no unique vertebrate species as in area 2, there were 12, including 2 rodents. The relationship for area 3, however, was not as pronounced because that area had nearly twice the plant species diversity of areas 1 and 2; and the greater plant species diversity may be responsible for the greater vertebrate diversity. If this is true, it is a direct reversal of the results obtained by Rosenzweig and Winakur (1969) in the lower-Sonoran desert scrub vegetation. They found that "the variation in plant species diversity failed to explain the variation in animal species diversity and that some of the most faunally diverse areas had the fewest species of plants." The three areas reported in this study, however, are in the Great Basin cold desert, which varies considerably from the Sonoran hot desert. It is possible that the amount and distribution of *A. tridentata* cover is only important in determining vertebrate distribution in areas with low total absolute cover as in areas 1 and 2 but not in area 3.

According to Pearson (1965a, 1965b) and Beatley (1969), primary productivity of *A. tridentata* communities peaks in late spring and early summer. Peaks in rodent populations in *A. tridentata* communities occur during the early summer to fall period (Turner, 1950; Sullivan, 1961). Trojan (1970) has shown that in a Polish grassland the rodent biomass increase during the summer is four times as great as during the winter and two times as great as during the spring. Summer and autumn increases accounted for 89 percent of the annual increase. He stated that "winter increases are of almost no importance to assessment of energy flow (3.2 percent)." His results may be applicable to the Great Basin sagebrush zone because its increased elevation could partially compensate for the higher latitude and much lower elevation of Poland. The Polish study was done in a grassland, but the areas studied in Rush Valley, Utah, were probably grassland before the valley's settlement (Christensen and Hutchinson, 1965). Winter production may be important in some sagebrush areas, but no winter data were taken in this study due to inaccessibility.

If (1) the annual peak primary production of *A. tridentata* communities was late spring and early summer, (2) rodent populations in *A. tridentata* communities peaked in the early summer to fall, and (3) there was little increase in rodent biomass during the previous winter months, then the population, mean species weights, and biomass data collected during this study should illustrate the dynamic relationships of the three study areas.

## Estimated Populations

The total population estimates of all species are shown in Table 3 and Figure 1. Area 1 had a definite early summer population peak followed by a steady decline and a leveling off in the fall, but area 3 had three different population peaks during the summer with the highest population occurring in late summer (approx. August 13). Area 3 had a gradual increase in rodent numbers, peaking in late summer (approx. August 13) and declining by September 3.

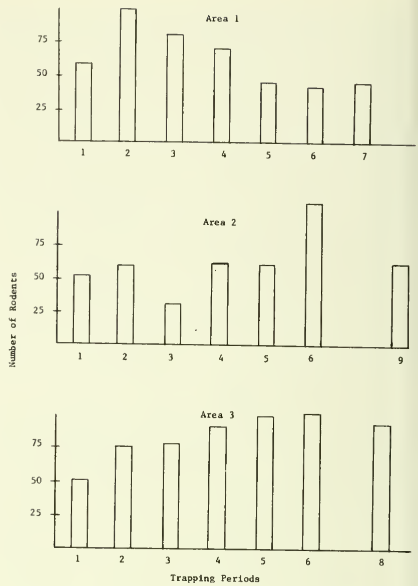


Fig. 1. Number of rodents estimated in all areas.

## Mean Species Weights

Mean species weight is not only important in calculating the estimated rodent biomass, but Walkowa (1970) pointed out the importance of species weights as an exploitation compensation mechanism in rodent populations. He found that reproduction operates as a compensating mechanism only if exploitation exceeds 31 percent. When exploitation was 0-30 percent, an increase in exploitation caused an increase in the production of biomass. In this study there appeared to be no unusual predatory or disease exploitation of populations above 30 percent; thus the species were likely reacting to exploitation by increasing biomass without increasing reproduction. This was further evidenced by the lack of high-population densities. The greatest estimated rodent density was eight rodents per acre (3.24 ha) in area 2 during its summer peak.

In addition to rodent weights varying with population exploitation, they also vary with the animal's daily activities. Tevis (1955) showed that the gross body weight increase in chipmunks going from an empty stomach to a full stomach averaged 6-8 percent, whereas Evans (1949) observed that voles increased 20 percent in body weight within five minutes after water consumption. It is evident, therefore, that an accurate biomass estimation requires use of weights from the particular time and population being considered. Mean species weights used in this study were calculated from what was believed to be the most accurate weight according to the above criteria, but errors may have occurred.

*Area 1.* The mean species weight of *P. maniculatus* was greatest in the early spring and then oscillated between lower weights throughout the study. The high weight during period 1 reflected the population structure at that time. There were few juvenile and subadult animals compared with subsequent periods. After period 1 there were increased numbers of juveniles emerging from the nests, causing a sharp decrease in mean species weight during trap period 2. For the remainder of the study reproduction caused oscillations in the mean species weights between trapping periods. These oscillations were expected since *P. maniculatus* is polyestrous (Asdell, 1964). The *E. minimus* mean species weights generally appeared to increase throughout the study to a peak near the end of the summer during trap period 5. This increase paralleled a gradual decrease in population numbers throughout the summer. The *E. minimus* reproductive pattern, one litter in the spring and subsequent growth of the young during the summer (Asdell, 1964), was responsible for the inverse relationship. No pattern was evident for *R. megalotis* because of insufficient captures.

*Area 2.* The mean species weight pattern of *P. maniculatus* in area 2 oscillated for the same reason as their observed oscillations on area 1, but the greatest mean species weight occurred in period 5. There was an apparent slow period in reproductive activity during June and July compared with area 1. This undoubtedly allowed the summer mean species weight of the population to peak later than in area 1. The mean species weights of *E. minimus* gradually increased during the summer because of their reproductive pattern. Too few *P. parvus* were caught in this area to show any definite patterns, but the same slow reproductive activity as noted in *P. maniculatus* on this area was also noted for *P. parvus*.

*Area 3.* The mean species weight pattern of *P. maniculatus* showed reproduction occurring throughout the summer. The *P. parvus* pattern in area 3 showed increased population numbers associated with decreased mean species weights throughout the study. This was expected since *P. parvus* is polyestrous (Asdell, 1964). Too few *E. minimus* were caught on this area to show any definite pattern.

## Biomass

The total estimated seasonal biomass in each area (Table 3 and Fig. 2) was similar to the population estimate for the area (Fig. 1). In terms of biomass, however, there was clearly a closer relationship between areas 1 and 3 than had previously been proposed. Biomass in area 2 showed that secondary production was rather unstable compared with areas 1 and 3.

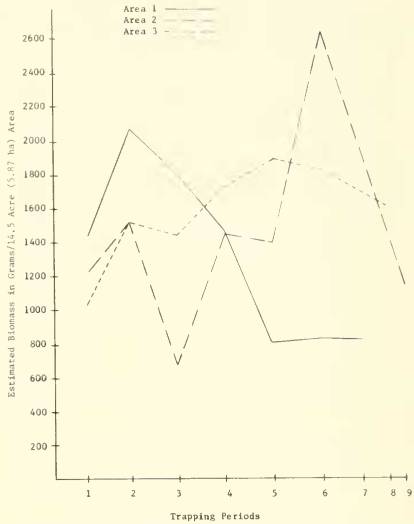


Fig. 2. Estimated total small rodent biomass by trapping periods.

*Area 1.* An early summer increase of 50 percent in rodent biomass was evidenced in area 1 during a 13-day interval between trap periods 1 and 2, which made trap period 2 appear as the peak period of summer rodent biomass production for area 1 (Fig 2). There was then a steady drop in biomass over a 42-day period followed by a leveling off. The data indicates, however, that the number of *E. minimus* and *R. megalotis* may have been overestimated during period 2. There were 39 *E. minimus* estimated during period 2, but only 29 were handled. There were also 4 more *R. megalotis* estimated than were actually handled. A high number of unmarked animals being caught at the end of a trap period would cause a high unmarked-to-marked animal ratio to occur. This high ratio would in turn cause an overestimation of the population. This high ratio may be caused by immigration of animals into the area, by new animals emerging from their nests, or by various other factors. In this instance the possible overestimation may have been caused by new juvenile male chipmunks becoming available to the traps.

If the actual number of rodents handled

during period 2 is used in the biomass calculation, then the summer peak on area 1 did not occur during trap period 2 but during trap period 3. The possible correction is shown in Figure 3. The total pattern for the summer, however, is still one of an early peak in rodent biomass followed by a steady drop and then a leveling off for the remainder of the study. This is what could be expected for a community in poor soil with low plant species diversity, as area 1 was earlier shown to be. Secondary production peaked early in the summer, after the observed peak primary production, thus placing greater demands upon the primary production of the community to support the increased secondary production. The plant community, beyond its peak production and with very little diversification, likely could not produce more food for the increased rodent population, so the rodent population rapidly declined to a level reflecting the probable carrying capacity of the community and then remained there through the end of the summer. Because of poor soil and other factors, the carrying capacity was low, approximately 55 g of rodent biomass per acre (22.27

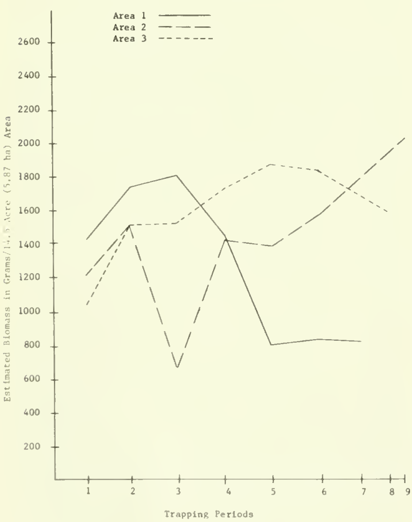


Fig. 3. Estimated total small rodent biomass by trapping periods using possible corrections.

g/ha). This low carrying capacity could have supported no more than one *E. minimus* and one *P. maniculatus* per acre (.24/ha).

*Area 3.* The rodent biomass of area 3 showed an entirely different pattern than area 2 throughout the summer (Fig. 2). Secondary rodent productivity increased rapidly after spring reproduction and was then followed by a short period of reduction before rising again. This reduction may have been due to a number of factors but was most likely caused by cold temperatures. The *P. parvus* estimate for the period of biomass drop (trap period 3) was considerably less than the previous estimate. This rodent, as a protective behavioral adaptation, regularly goes into a state of torpor when it encounters cold (Bartholemew and Cade, 1957; Beer, 1961; Morrison and Ryser, 1962; Chew et al., 1965, 1967; Tucker, 1962, 1963, 1965a, 1965b, 1966). During the second and third nights of trap period 3 the coldest summer temperatures were recorded for area 3, and four *P. parvus* that probably would have been caught had the nights been warmer were not recaptured. This could have led to a low population estimate and thus a low biomass estimate for the period. If this were the case, then the biomass of area 3 would have shown an increase from trap period 1 to its peak in trap period 5. The possible correction is shown in Figure 3. At the end of the summer peak biomass gradually declined. Because of the diversity of the plant community in area 3, favorable climatic conditions and primary production were probably sufficient to supply food for the gradual summer increase in secondary production.

*Area 2.* The graphing of rodent biomass for area 2 showed no pattern similar to areas 1 or 3. It did, however, show an early summer decline in standing crop, a rapid recovery with leveling off for a trap period, a midsummer biomass increase to a peak higher than in either areas 1 or 3, and a late summer decline in standing crop of the same rate as that which occurred in the early summer.

Close examination of the data, however, for the *E. minimus* population showed a large trap mortality during period 6. This caused Lincoln's index to overestimate the population. It estimated 20 more *E. minimus* than were actually handled, which would represent an overestimation of 1,060.5 g in biomass. Thus, at trap period 6 the high peak shown in Figure 2 would probably be much lower. The possible correction is shown in Figure 3. With this correction the biomass was below that of area 3 for the same period.

Closer examination of the data revealed another possible error. In trap period 9 there were 29 different *E. minimus* handled, but because this period was a kill-trap period, the diurnal chipmunks were not caught during the one live trap night. As a result, none were marked, and no population estimates were made on day 2 of the kill-trap period. There were 17 different chipmunks handled on days 1 and 2 of this period. If the biomass of these rodents were added to the total biomass of this period, it would raise the total by 879.7 g. This possible correction is also shown in Figure 3.

The above corrections change considerably the estimated summer biomass pattern of area 2. The pattern now becomes one of an early summer decline in biomass, a recovery period, a period of no increase or decrease in biomass, and a steady rise in biomass that may not have peaked before the study ended. In terms of stability the community of area 2 appeared to be less stable than those of areas 1 and 3. The corrected pattern showed that in terms of biomass area 2 was more similar to area 3 than area 1 as had been previously proposed.

## Conclusions

It appeared that when the characteristics of (1) vertebrate presence and distribution, (2) plant presence and distribution, (3) comparative rodent population numbers, and (4) comparative rodent biomass of the areas were considered, the three areas were in three different climatic or edaphically induced successional stages or conditions. Area 2 had the least diverse vertebrate presence. This may have resulted from the *A. tridentata* cover being composed of small bushes representing the greatest percent cover composition of the three areas. Area 2 was the least stable in terms of the annual cycle for rodent populations and biomass increase, probably a result of the poor plant species diversity. Area 3 had the most diverse vertebrate presence and was the most stable in terms of the annual cycle for rodent population and biomass increase. This may have been due to the *A. tridentata* cover pattern, which was opposite that found in area 2, and/or to the increased plant species diversity found in area 3. Area 1 appeared to be intermediate, in its vertebrate presence and *A. tridentata* cover patterns, to areas 2 and 3. Its annual cycle in terms of rodent population and biomass increase showed the earliest peak of the three areas. This may have been due to poorer soil and climatic conditions causing an early peak in primary productivity, a subsequent early peak in rodent productivity, and an extended period through the rest of the summer when conditions did not favor either primary or secondary production.

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